N.A.A.S. QUARTERLY REVIEW

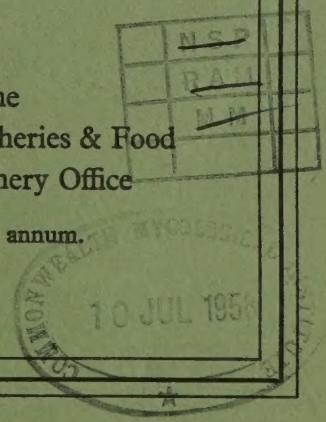
NUMBER

40

Summer 1958

London
Published for the
Ministry of Agriculture, Fisheries & Food
by Her Majesty's Stationery Office

PRICE 2*s.* or 9*s.* 4*d.* per annum.



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QUARTERLY REVIEW

The Journal of the National Agricultural Advisory Service

NO. 40 SUMMER 1958

Contents

ARTICLES

Digestion in the Ruminant . . . . . *A. T. Phillipson* 231

Johne's Disease: A Problem of Yesterday, Today and Tomorrow *N. H. Hole* 242

Mechanization and Management . . . . . *C. Culpin* 247

REVIEW

Milk By-Products for Animal Feeding . . . *S. M. Boden* 253

REGIONAL NOTES

Sheep on the Romney Marsh . . . . . *R. Duncan* 266

Evaluating Advisory Work from Leaflet Consumption *A. R. Staniforth and F. W. Keighley* 273

Single copies price 2s. (2s. 4d. by post). Annual Subscription 9s. 4d., including postage. SALE INQUIRIES *should be addressed to the publishers at any of the addresses overleaf.* EDITORIAL COMMUNICATIONS *should be addressed to the Editor, N.A.A.S. Quarterly Review, Ministry of Agriculture, Fisheries and Food, Room 215, Great Westminster House, Horseferry Road, London, S.W.1.*

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REVIEWS AND ABSTRACTS

In this section of the N.A.A.S. Quarterly Review, it is intended to survey current research and experiment in agriculture, horticulture and the allied sciences applicable to the work of the National Agricultural Advisory Service. It will not be possible, of course, to cover more than a small part of this wide field in each issue.

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Digestion in the Ruminant

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THIS SUBJECT was reviewed ten years ago* and the main features of digestion in the rumen were outlined. Since that time a great deal of work in many parts of the world has added both depth and detail to the picture and has extended it beyond the previous background. Several detailed reviews of this subject have been published, and reference to these should be made for further information, and for the sources of the experimental work upon which this article is based.

The Young Ruminant

Normally when the young ruminant sucks its mother the milk passes directly to the abomasum owing to reflex closure of the oesophageal groove. The rumen of the young animal contains bacteria many of which are lactobacilli, and direct passage of milk to the acid environment of the abomasum where peptic digestion occurs is a means of avoiding undesirable bacterial degradation of the milk constituents. The flow of gastric juice seems to be well established in lambs 48 hours after birth, so that it is unlikely that any extensive changes due to ingested bacteria occur in this organ. A certain amount of back-flow of milk from the abomasum to the rumen can be seen radiologically to occur in young goats and calves, and the rumen, although undeveloped, always contains some liquid. Part of this may be saliva. Casein coagulates rapidly in the abomasum, and the material flowing backwards to the rumen is presumably similar to whey. Salivation in the newborn animal is undeveloped as far as the parotid gland is concerned [8], and the age at which augmented reflex salivation develops in response to feeding and other stimuli is likely to be important in determining how soon it is wise to allow the young ruminant to eat dry meals that are easily fermented in the rumen. Parotid saliva is a bicarbonate phosphate buffer, and is one of the important factors that controls the reaction of the rumen, and prevents the contents of the organ becoming excessively acidic.

Young lambs start to nibble grass when about 14-18 days old, and calves begin when about three weeks old. With calves, the presence of short-chain fatty acids in the rumen at one month indicates that fermentation as a digestive process is already established. The character of the fermentation seems to change during the first three months of life, and in the early stages a lactic acid fermentation is probably more accentuated than later on. Protozoa do not appear in the rumen until calves are about one to two months old, and contact with normally

*N.A.A.S. Quart. Rev., No. 2. 1948, pp. 55-62.

infected animals appears to be necessary since no one has yet proved the existence of free living forms of these organisms. The origin of the numerous kinds of bacteria in the rumen is not known, but a large number no doubt are ingested with the feed. Cud inoculation to hasten the establishment of an adult type of flora in the rumen has been advocated, and there is no doubt that it establishes a protozoan population more rapidly than it would otherwise occur. No clear benefit to the animal has, however, been established. Feeding of good quality hay has also been recommended since this encourages the establishment of an adult type of bacterial population as far as this can be judged by its microscopical appearance, but whether the hay or the organisms are responsible for the improvement in the animals is uncertain.

Digestion in the Rumen

CARBOHYDRATES

Bacteria capable of fermenting practically all fodder carbohydrates—including those found in seaweed—have been isolated from the rumen and are present in sufficient concentration to indicate that they can cause extensive degradation of these materials in the rumen. Pentosans, on which very little work has been done, are known to be fermented by mixed rumen organisms, but no individual strains of bacteria have yet been studied owing to the difficulty of obtaining a pure substrate.

Carbohydrate fermentation results in a mixture of short-chain fatty acids, and absorption of these acids occurs in the rumen. A lactic acid fermentation is set up when large quantities of flaked maize are fed; this is associated with a decreased proportion of acetic acid and an increased proportion of propionic acid in the rumen as the result of the further fermentation of lactic acid to acetic and propionic acid in which the latter acid predominates.

The protozoa play an interesting role in carbohydrate fermentation, for they seem to be responsible for the rapid utilization of soluble fodder carbohydrates, part of which is converted into storage carbohydrate of the amylopectin type within their cytoplasm. The soluble products of carbohydrate fermentation by protozoa are again short-chain organic acids, and, if starved, they use their storage carbohydrate and yield acetic, butyric and lactic acids. Many of the rumen cocci form capsular polysaccharides which are distinct from the polysaccharide-like material found inside the cells of these organisms which possess this property. The contribution that these bacterial and protozoan carbohydrates make to the nutrition of the host will be discussed later.

PROTEIN AND OTHER NITROGEN-CONTAINING MATERIALS

McDonald [9] pointed out the importance of ammonia as an indication of the overall nitrogen metabolism in the rumen as the concentration present represents the balance between its production, utilization and absorption. He observed that after the introduction of

different proteins into the rumen different concentrations of ammonia occurred in the rumen liquor. As amino-nitrogen and not ammonia nitrogen is needed by the animal for metabolism and production purposes, Synge and his colleagues at the Rowett Institute have studied the metabolism of proteins and amino-acids by mixed rumen organisms, and the relative values of several protein concentrates for growth in lambs and milk production in goats and cattle.

There appears to be a relatively steady rate of hydrolysis in the rumen of proteins; the amino-acid concentration is very small and the ammonia concentration variable. Of several protein concentrates, groundnut meal produced the highest concentrations of ammonia in the rumen, while fresh pasture grass is also associated with high ammonia production, a fact that has been amply confirmed in New Zealand. Rumen bacteria utilize amino-nitrogen not only for growth, but also probably the carbon residues for energy requirements. Laboratory studies with casein hydrolysates or with mixtures of amino-acids have shown that rumen bacteria rapidly deaminated amino-acids with the production of ammonia, a mixture of short-chain fatty acids in which the proportions of isomers of C_4 and C_5 acids are accentuated, and carbon dioxide.

The utilization of ammonia by rumen organisms has received less attention. If the rumen liquor of sheep fed on different rations is collected and incubated for $2\frac{1}{2}$ hours under carbon dioxide, the ammonia concentration in the liquor increases if the animals are fed on grass, hay, or hay with a protein supplement. The increases observed with hay are much less than those from the other rations. If, however, they are fed on a ration of hay with a concentrates supplement consisting of flaked maize and paisley meal in the proportions of 10:1, the ammonia concentration in the rumen liquor is very small. Increasing the concentration by the addition of ammonium chloride and subsequent incubation for $2\frac{1}{2}$ hours leads to loss of the added ammonia, and the use of ammonia labelled with ^{15}N shows that the isotope becomes concentrated in the protein that can be precipitated at the end of the experiment. Under these circumstances there is little doubt that bacteria capable of incorporating ammonium nitrogen in their protoplasm are present. Warner [13] has found that mixed rumen organisms still use ammonium nitrogen even in the presence of a variety of amino-acids. From the rumen contents of sheep fed the flaked maize ration lacto-bacilli have been isolated that, in the presence of cysteine, reduce the ammonia present in the media used. This effect occurs not only in media in which cysteine is the only amino-acid present but also in media containing peptone as well [3].

The balance between ammonia production and ammonia utilization in the rumen may influence the value of the protein fed, and under most circumstances production is greater than utilization. The only known way of reducing the concentrations of ammonia in the rumen

liquor of sheep fed on rations containing a lot of protein is to add starch, which appears to encourage the presence of bacteria which utilize ammonia nitrogen. This is in keeping with the mass of work on the use of urea done in the U.S.A., which indicates that soluble carbohydrate must be fed in adequate quantities, if the urea is to be of any use to the animal. A great deal more work on the bacteriology of this aspect of the problem is needed.

Protozoa also produce ammonia, but no further work has yet been done on their nitrogen metabolism. Salivary urea is also a source of rumen ammonia since urea is rapidly hydrolysed by rumen organisms; the mucoproteins of saliva are another possible source, but this remains to be explored.

There is little information on how much dietary protein leaves the rumen intact. McDonald [10] estimated that 40 per cent of the nitrogen of zein was converted to microbial protein in sheep. It is probable that a much larger proportion of grass proteins are attached in the rumen as zein itself does not cause large increases in the ammonia concentration in the rumen. Synge [12] suggests that it would be desirable to investigate the processing of protein supplements designed for cattle and sheep in order to render the protein less readily available to bacterial attack so that more of it passes to the abomasum for normal peptic digestion.

Absorption of ammonia is known to occur from the rumen, and there is evidence that one important factor in regulating the quantity disappearing in this way is the concentration. The content of ammonia in the peripheral blood is very small indeed unless protein feeding is heavy, and even then it is small compared to the concentration in the rumen. The concentration gradient therefore is in favour of absorption, and experimentally it can be shown that absorption increases the higher the concentration in the rumen.

The quantity of nitrogen excreted in the urine is related to the ammonia concentration in the rumen so there are reasonable grounds for supposing that the nitrogen of rations which produce high concentrations in the rumen are not so economically used as those producing low ones. Chalmers, Cuthbertson and Synge [4] found experimentally that with pregnant ewes in a state of negative nitrogen balance, the supplementation of the ration by a casein hydrolysate introduced into the rumen was ineffective in restoring nitrogen balance, presumably as the amino-acids were rapidly deaminized and most of the nitrogen absorbed as ammonia. Introducing the hydrolysate into the duodenum, so that amino-nitrogen could be directly absorbed, resulted in a better nitrogen retention. The question of the significance of ammonia production under practical feeding conditions from experimental work has been summarized by Synge [12] and indicates that in fattening rations it is unlikely to be important, but that when concentrate mixtures similar to those fed to dairy cows are used to supplement rations

otherwise low in available nitrogen, then the net loss of ammonia from the rumen many be critical in determining the value of protein fed.

FAT

Fat forms only a small proportion of the food eaten; the dry matter of cocksfoot contains from 2 to 4 per cent of long-chain fatty acids, C_{16} and C_{18} acids predominating in the unsaturated form. Since the body fat of ruminants contains saturated acid almost exclusively, and since the administration of oils does not alter it, the action of rumen bacteria on fats has been investigated, with the result that they are now known to have the property of hydrogenating unsaturated fatty acids.

The Passage of Food through the Gut

Delay in the onward passage of food or food residues through the alimentary tract of any animal occurs in the large intestine. In animals with a simple stomach, delay in this organ is not excessive, and a meal has usually left it within eight hours of ingestion. The large and complicated stomach of the ruminant causes greater delay to the passage of food, and it takes about 24 hours for half the food residues of any feed to leave the rumen. The rumen never empties, so each meal becomes mixed with the residues of previous meals. The method of mixing in the reticulum and rumen seems to depend to a large extent on movement of water caused by the contractions of the pillars and walls of the organ. The contents of the reticulum and anterior sac of the rumen exchange regularly owing to the reciprocal movements of these cavities; the contents of the dorsal sac which receives a new meal is frequently flushed by the more fluid contents of the ventral sac. What is not well understood is how material from the rumen passes back into the anterior sac of the rumen which freely communicates with the reticulum from where food passes on to the omasum. Passage to the omasum occurs, as far as is known, after every biphasic contraction of the reticulum, and it appears as though a differential rate of passage of solid and liquid material occurs through this organ.

The volumes of food passing from the abomasum to the duodenum and from the end of the ileum to the caecum in sheep have been measured recently by Hogan [7], and the figures give some indication of the importance of water-flow through the alimentary tract. A sheep secretes anything from 5 to 8 litres of saliva daily and may produce from 3 to 5 litres of gastric juice in the abomasum. In sheep, about four times as much water leaves the stomach as enters it in the food and drinking water, but this does not account for the large volume of water entering the rumen in the form of saliva, or the abomasum in the form of gastric juice. Water absorption is known to occur in both the rumen and omasum, and it seems as if the quantity absorbed may be as much as 5 to 6 litres per day. The water entering the caecum is about half the quantity entering the duodenum, and as the bile, pancreatic and

intestinal secretions are added, the volume of water absorbed in the small intestine is greater than the 4 litres lost between the duodenum and the caecum per 24 hours. A further loss of 4 litres occurs from the caecum to the anus. The volume of water circulating between the blood and the alimentary tract is large, particularly when compared to the plasma volume, which is not greater than 3 litres.

Losses of digestible dry matter between the mouth and duodenum through absorption are about 70 per cent of the total; a further loss of about 10 per cent occurs in the small intestine and the remainder in the large intestine. The figure of 70 per cent loss in the rumen agrees well with an estimate of the loss in the rumen and reticulum of cattle recently made by Balch *et al.* [2]. The position for nitrogen is different, and Hogan [7] calculated that about 30 per cent of the apparent total loss through absorption occurred in the stomach and practically all the remainder in the small intestines.

The passage of food to the abomasum seems to be at a maximum from 2 to 4 hours after feeding, for in this time the volume of the contents about doubles itself; thereafter it slowly declines until the next meal. A similar increase in the contents of the small intestine occurs but its peak is delayed to a later time than in the abomasum.

Rumination

This subject has received little attention until recently. Initially, all the emphasis was laid on a study of the mechanism of rumination, and two major hypotheses were put forward in France towards the end of the nineteenth century. One proposed that the principal force moving food into the oesophagus was increased intragastric pressure, the other proposed that the principal force concerned was decreased intrathoracic and consequently intra-oesophageal pressure. The first hypothesis was believed until the 1930s, but thereafter the second hypothesis was accepted because evidence in its favour was greater. A third hypothesis, however, was proposed by Wester [15] but has never been generally accepted. Wester supported the second hypothesis in that he considered that food entered the oesophagus largely as a result of aspiration than an increase in intragastric pressure, but he contended that the oesophagus itself was the organ concerned in producing a fall of pressure within its lumen, and that the inspiratory effort with a closed glottis—which certainly occurs—has little effect. It was held until about a year ago that cattle or sheep could only ruminate with difficulty if a tracheal cannula were inserted and left open; this report supported the idea that an inspiratory effort was involved. However, Webster and Cresswell [14] have found that rumination in sheep occurs as easily with an open trachea as with a closed one. There is no published account of critical measurements of pressure on the gastric side of the cardia at the moment of regurgitation, but from changes of

pressure in the reticulum it appears to occur after the main rise in pressure due to the first of three reticulum contractions.

A further point of interest is that cattle and sheep in which the reticulum has been immobilized by atropine can still regurgitate without effort. The fall in pressure within the thoracic oesophagus has been recorded, but more exact measurements are needed to establish its magnitude. It seems that Wester was probably right and that the thoracic oesophagus itself may be the principal organ concerned. It receives its nerve supply from the dorsal thoracic root of the vagus and is known to be an active organ from radiological observations. The cud that enters the thoracic oesophagus is liquid, and in small ruminants it can be seen radiologically at regurgitation that the whole thoracic part of the oesophagus is filled. A contraction then starts in the thoracic oesophagus several inches in front of the cardia, and the material oral to this is carried to the mouth by a wave of antiperstalsis while the material caudal to it returns to the reticulum. Very soon after the cud reaches the mouth, liquid is swallowed at intervals while the animal is chewing. Finally the bolus of solid matter is swallowed and returns to the reticulum or anterior sac of the rumen.

Studies on the incidence of rumination by Gordon [5] show that in sheep more time is spent ruminating between 8 p.m. and 8 a.m., while during the daytime rumination is more spasmodic and irregular. The effect on the pattern of rumination of varying the time of feeding throughout the 24 hours showed that this general pattern remained the same except when the feed was given at night, when the main period of rumination was delayed, presumably because the animal cannot eat and ruminate simultaneously. Gordon's general conclusion is that the pattern of rumination is determined mostly by habit, for this seemed to dominate any possible chemical relation to feeding. Short of surgical interference to the central nervous system, the only condition that seems to alter the pattern of rumination is to grind all the food to a fine powder which reduces the time devoted to this occupation. This presumably is due to lack of stimulation to the sensory pathways originating in the sensitive areas of the reticulum and rumen.

The Nervous System and Movement of the Stomach

Normally the contractions of the reticulum and rumen are regular and co-ordinate, although changes in the pattern of movement occur with the activity of the animal. With cattle, the incidence and strength of the various movements are increased during feeding, while during rumination a change in the pattern of movement occurs in both organs. During rest more variation is found than during the other two activities. Experimentally, a number of reflex effects can be demonstrated; for example, distension of the abomasum inhibits reticulum contraction, but this result is reversed if both splanchnic nerves are cut; distension

of the reticulum itself causes reflex contraction of this organ, and the same result may be obtained by stimulation of the reticulo-ruminal fold or by stimulating the anterior wall of the reticulum itself. There is little doubt that a great many gastric and gastro-intestinal reflexes remain to be discovered, and that reflex secretory activities are also concerned. Already there is some evidence that parotid secretion and reticulum contractions are associated. It is one thing to demonstrate the basic mechanism and quite another thing to appreciate what it may mean in the normal animal, and it remains to be seen whether the movements of the reticulum and rumen and the changes in pattern of movement that occur can be adequately explained on a reflex basis.

Absorption

The mixture of fatty acids entering the blood stream from the rumen is similar to the mixture in the rumen, but contains less butyrate. This is because butyrate is metabolized by rumen epithelium, and a considerable part is converted to ketone bodies of which B-hydroxybutyrate predominates. Propionate is also metabolized by isolated rumen epithelium, but this does not seem extensive enough *in vivo* to make any noticeable difference to the mixture of acids leaving the rumen in the blood.

A potential difference exists between the rumen contents and the blood stream, and the rumen is negative to the blood usually by some 25 to 34 mV. This force offers an explanation of why the chloride ion can be absorbed against a concentration gradient. Sodium, on the other hand, is also absorbed from solutions when its concentration is similar to that of plasma, and being a positively charged ion, this presupposes that an active mechanism exists to cause its transference from the rumen to the blood. Recent work from Belgium [11] indicates that active absorption of sodium also occurs in the omasum. Inorganic phosphate, although present in the rumen in concentrations that are about ten times those of the plasma, is not absorbed to any appreciable extent, while potassium is absorbed slowly, the concentration in the rumen being very much higher than it is in the blood. The rumen epithelium, therefore, is a selective membrane and is not equally permeable to different ions.

Volatile fatty acids are absorbed from the omasum and also carbon dioxide—presumably in the form of bicarbonate. An exchange between total carbon dioxide and chloride occurs, and the material at the lower pole of the omasum has lost both volatile acids and total carbon dioxide and gained chloride.

The Abomasum

The material entering the abomasum has changed very much from the material eaten by the ruminant. It has lost about 70 per cent of the digestible fibre; most of the starch has disappeared; soluble sugars have been fermented; and a considerable portion of the furfuraldehyde-yielding materials—a measure of pentosans—has disappeared. It is still not known how much protein and non-protein nitrogen is converted to bacterial and protozoan protein. It is clear that there is loss of nitrogen through absorption which, for one ration, according to Hogan's work, apparently amounts to not less than 30 per cent of the total, but this is likely to vary with composition of the feed. In place of these losses the food has gained micro-organisms—both protozoa and bacteria; a large quantity of short-chain fatty acids have been produced, most of which are absorbed before the material reaches the abomasum; it has gained B vitamins, including B_{12}; it has lost carbon in the form of methane and carbon dioxide; it still contains some ammonia. Among inorganic constituents it has gained phosphate and chloride; lost some potassium, since the concentration in saliva is usually low except in sodium-depleted animals; and has gained sodium, for there is usually little sodium in the food unless salt is added or given as a lick, and the large quantity secreted in the saliva is not all reabsorbed before the material reaches the abomasum. The gastric juice is secreted in quantities that give a dilution of about 1:1 to 2:1 for rumen contents; gastric juice is similar to that of other animals and is about a one-tenth normal solution of hydrochloric acid, although on occasion it may be less than this strength. It exerts peptic activity and has some mucus. In consequence, the non-protein nitrogen fraction of the abomasum is increased owing to peptic digestion. Protozoa are digested and bacteria lose their definition and staining properties when viewed microscopically. This does not mean that the contents of the abomasum are bacteriologically sterile. Attention has been given to how much bacterial or protozoan polysaccharide reaches the abomasum, and the available evidence suggests that it is not large. Heald [6] estimated that in hay-fed sheep it was about 5-6 g per 24 hours. Estimates of the glucose absorbed into the portal blood stream, when compared to volatile fatty acids in sheep on various rations, supports the concept that glucose derived by the animal from microbial synthesis of polysaccharides is comparatively small.

Absorbed Products of Digestion

It appears that whatever food is eaten, the products of digestion consist of:

1. a mixture of short-chain fatty acids;
2. a small quantity of sugars derived possibly from the food, although this is unlikely to be more than a trace, and from

microbial polysaccharides or any starch that may escape fermentation;

3. amino-acids derived from digested bacteria and protozoa, and any protein and amino-acids that escape to the abomasum intact;
4. B vitamins; and
5. ammonia.

Fat, unless fed as such, is unlikely to constitute much of the absorbed products. The quantity in fodders is small and the content of bacterial lipids amounts to about 17 per cent of the dry weight. Carbon dioxide and methane are also produced, but the very low solubility of methane means that little if any is absorbed.

The short-chain fatty acids, from estimates of their excess in the portal blood flow, seem to be absorbed in quantities that are nearly if not entirely calorifically equal to the calorie expenditure of fasting sheep. Recent investigations by Armstrong and Blaxter [1] on the heat increment induced by the administration of acetic, propionic and butyric acids to fasting sheep show that the heat increment produced by a mixture of all three acids is much less than the sum of the heat increment derived from these acids when given individually. The opinion that was sometimes expressed that the energy of acetic is lost to the animal as heat is therefore very far from true. It would indeed be odd if it were true, as it is unlikely that ruminants which are widely spread through the world would be so uneconomical with their food.

A wide range of mixtures of the three acids were studied by Armstrong *et al.* [1], and it made little difference to the heat increment whether acetic was anything from 90 per cent to 25 per cent of the total, the other acids varying inversely. The heat increment in fasting sheep was only about 15 per cent, which is larger than would be obtained for glucose, but, even so, is much less than that expected from the results with individual acids. These results indicate that a small quantity of propionic acid is essential to obtain efficient use of acetic acid, but that otherwise the proportions of the fatty acid mixture are of little consequence in the normal energy balance of the fasting sheep. Experiments in which acids were added to sheep on a super-maintenance ration gave higher heat increments for all acids, and the heat increments decreased from acetic to propionic to butyric acid.

The intermediary metabolism of propionic acid indicates that it enters the tricarboxylic acid cycle and causes an increase in the carbohydrate reserves of the animal; less is known of acetic acid, but it is known to form both milk and body fat, while the carbon enters a variety of other substances. Practically nothing is yet known of butyric acid beyond its ketogenic properties.

Plenty of questions remain to be answered, but the study of digestion and metabolism of the ruminant is slowly providing a more rational

picture of how these animals perform as they do on any given feeding regime, and also is providing clues that may prove useful in understanding the nature of the so-called "metabolic" diseases.

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Johne's Disease: A Problem of Yesterday, Today and Tomorrow

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POSITIVE IDENTIFICATION of the causative agent of a disease has, with few exceptions, been followed by the discovery of some means of treatment, control, or eradication. Johne's disease must be regarded as one of the exceptions. The organism was recognized as the cause sixty-three years ago and successfully cultivated seventeen years later, but despite the subsequent efforts of research no successful treatment or means of eradication have been discovered. Although vaccination methods have met with a considerable measure of success, complications that arise from their use have impeded their widespread application. A great deal more information is required about the processes of natural infection and about the factors which precipitate clinical disease, and no diagnostic method has yet been found satisfactory for the identification of all stages of infection in the living animal. Johne's disease may therefore be regarded as one which so far has largely defeated the efforts of research, since it still flourishes unchecked, and is to a considerable degree uncheckable.

Is the Disease Gaining Ground?

Research into Johne's disease has not had the stimulus of human hazard, but the great modern interest in maximum food production, and the higher standards of efficiency now essential for the successful farmer, have resulted in its exposure and a greater demand for control. It is debatable whether this disease is now more common rather than attracting more attention, although there is a body of opinion which holds that a bovine tuberculosis-free status is encouraging the spread of Johne's disease. There is no doubt that it has taken a heavy toll of cattle, sheep and goats since long before the end of the nineteenth century when it was first recognized as a specific bacterial disease. Nevertheless, there is no record of any attempt on an area or national basis to control it, and as would be expected this has resulted in a considerable dissemination of the infection. The extent of this infection is not fully appreciated because the disease has come to be associated almost entirely with the clinical form and its very striking symptoms and effects. It is important to realize that Johne's disease is a chronic infection, and unlike diseases such as foot-and-mouth where symptoms appear in a few days, an animal may carry infection for several years or perhaps for life without showing any symptoms at all. The clinical disease is *one* sequel to a long-standing infection; the evidence of recent years would suggest that it is far less frequently the invariable sequel than was at one time supposed. Two widely separated surveys of cattle passing

through abattoirs for meat have shown that roughly 15 per cent in each survey were infected with the Johne's organism, yet investigations into the causes of losses in cattle in a number of small areas of the country have attributed less than 1 per cent to clinical Johne's disease. It would be unwise to assume that either of these figures is representative of the country as a whole, but they do serve to suggest a considerable gap between the amount of infection and the amount of clinical disease.

There would seem to be some analogy here to tuberculosis, which may be tolerated by the individual unless stimulated into activity by debility or some other incidental factor. Conditions which stimulate or encourage the development of clinical Johne's disease are the subject of research today, because if it were found possible to control breakdown, the impact of the disease on agricultural economy would be greatly reduced. Even in herds where infection is recognized although clinical disease is infrequent, the threat of an extensive breakdown is always present—something that in several instances has been known actually to occur in herds where the presence of infection without clinical disease has been ignored. Several factors, such as husbandry, soil, water, climate, mineral deficiencies, or excessive milk production, have all been suggested at some time as "trigger mechanisms" for the onset of clinical disease; some breeds have been described as more liable than others. The evidence regarding any one of these factors is however far from conclusive; infection may be present in heavy or light milking herds, in beef herds, good or bad herds on wet or dry farms of various soil types, and in any of these clinical disease may or may not be a problem.

Calf Segregation is not the Complete Answer

Another aspect of this disease with an important bearing on attempted control or eradication is the age at which infection occurs. For a considerable time the view has been held that cattle become infected in calfhood, a contention supported by the fact that it has proved very difficult to infect cattle by experimental means if they are over a year old; indeed the best results have been obtained by using calves less than 6 months old. The organisms excreted in the dung by infected, particularly by clinically affected, animals, have been generally accepted as the only sources of natural infection. Attempts have therefore been made to clear affected herds of this disease by removing all calves at birth and rearing them completely isolated from adult stock and pasture used by adult stock. These segregation methods do appear, in some instances, to have reduced the incidence of the disease, but they do not appear to be capable of eradicating it. There are at least two explanations for the failure of what appears to be a sound theory.

Although a claim was made in 1929 that the Johne's organism could be cultivated from the unborn foetus of an infected cow, it was not until considerable confirmatory evidence was obtained in 1955 that

any notice was taken of this most important observation. The more recent findings are that 50 per cent of calves carried by clinically affected dams are infected with the organism before they are born; there is no evidence available about the calves of infected but non-clinical cows, but, even if these are found to be an insignificant risk, the fact remains that it has long been a common practice to keep a clinical case if possible long enough to salvage the calf. This means that some of the animals in the calf-segregation experiments may have been already infected when born and a source of danger to the other isolated animals. Another explanation that could be offered to account for the failure of calf segregation is that it is unwarranted to accept an age bar to natural infection on purely experimental evidence. There is quite an amount of circumstantial evidence to suggest that adult infection may be a factor to contend with in the natural disease. It is not at present thought that pre-natal infection accounts for more than a limited proportion of natural cases, for although the disease frequently occurs in families, the possibility of an hereditary susceptibility to infection cannot be ruled out.

When tuberculosis eradication in cattle was first envisaged a similar problem of latent or non-clinical infection had to be considered. There was, however, one very vital difference—tuberculin was then regarded as, and has since proved to be, a highly reliable diagnostic agent for all stages of infection. There is no parallel in the case of Johne's disease. Much attention has been paid to johnin, a comparable preparation to tuberculin, but this does not appear to be sufficiently accurate or sensitive enough to be of practical value in an eradication scheme. The complement fixation blood test seems to be a more promising proposition, but although this has been found to have a high degree of accuracy in suspected cases it appears to have limitations as a means of detecting occult infection, and its use for this purpose is still only at an experimental stage. It is known to fail in cases of early infection, and although it is thought to give a good percentage of reactions in cases where the disease is established without symptoms, its specificity has still definitely to be proved.

Even Control has its Drawbacks

At the present time, therefore, as a successful method of treatment is unknown, and eradication would seem to depend on the discovery of a more sensitive means of identifying latent infection, attention is focused on control. It is possible to control a disease without having to diagnose infection in the individual animals. There are two very different approaches to control. One is to attempt to rear animals free from exposure to infection, and the other is to protect them against infection by some form of vaccination. The difficulties of rearing animals free from the risk of infection have already been discussed.

Vaccination depends primarily on the availability of an efficient vaccine that will confer a lasting immunity. A method of vaccination devised in France in 1926 has been extensively used there in certain affected areas, and is reported to have given very favourable results. A modification of this French method has been applied to all the calves born in certain selected experimental herds in this country, and appears to have brought the disease under control in these herds. Johne's disease was introduced into Iceland nearly twenty years ago and developed into a serious menace to the sheep; vaccination is being used there on a very considerable scale, and the results so far obtained are very favourable. There is therefore considerable evidence that vaccination is an effective means of controlling the disease, but nevertheless there are some very considerable objections to its general application. In the first place, the present method requires the development of a permanent nodule under the skin at the site of inoculation; this may be as large as an orange, or rarely larger, and is regarded as a blemish. Secondly, no importing country will take a vaccinated animal. Thirdly, vaccination against Johne's disease promotes a tuberculin sensitivity, and although this is usually predominantly avian there is some doubt as to whether bovine tuberculosis in a Johne's-vaccinated animal could invariably be detected by the tuberculin test. Today, vaccination in this country is the subject of considerable further experimentation, and its effect on tuberculin tests is being carefully examined. It is obvious that in a country where bovine tuberculosis is on the verge of being totally eradicated, the advantages that might be obtained from the widespread use of vaccine must be very carefully weighed against the risk of upsetting a programme that has taken over thirty years to mature.

A Hard Nut to Crack

Those are the cardinal points about the diagnosis and possible methods of control of Johne's disease in this country at the present time. The problem might be likened to a very hard nut that has yet to be properly cracked. Doubts may be expressed in some quarters as to whether it is a problem of sufficient national importance to warrant further extensive investigation and what will be very expensive attempts at control or eradication. No one who has been closely associated with Johne's disease can have any doubts on this point. The long and variable period of pre-clinical infection and the absence of holocausts such as are seen with foot-and-mouth disease give a very misleading impression of its economic significance. The clinical disease is most common in cows in their prime, after the second or third calf, and if the figure of 1 per cent clinical cases per year is taken as a rough guide, this could represent 50,000 prime animals in Great Britain, or a minimum annual loss of $2\frac{1}{2}$ million pounds, a figure which does not take into account pedigree values and loss of productivity, or losses in sheep. The average annual compensation paid out for foot-and-mouth disease over the past eight

years is less than a quarter of this sum. In the absence of human risk, this disease may appear to many farmers with the occasional clinical case to have only a nuisance value, but if infection is present in a herd the potential for heavy loss is there too, and no effort should be spared to curtail the enormous annual wastage.

How Farmers can Assist

What advice can be given to the farmer in trouble over Johne's disease or anxious to avoid trouble? Unfortunately we do not know how best to deal with this problem at present, and this fact should be admitted. The first need is a lot more research and investigation, and in the writer's opinion one of the biggest factors for success will be the co-operation of the farmer himself. This disease, with its protracted period of incubation and no satisfactory susceptible small experimental animal, does not readily lend itself to laboratory investigation, and much of the essential information that is necessary before it can be properly dealt with will have to be obtained from the field. There has been, and still is, a marked tendency to conceal the presence of Johne's infection; if farmers would freely admit their suspicions or problems concerning Johne's disease to their practitioner or veterinary investigation officer, and co-operate as far as possible in any enquiry or investigation required, this would be a big step towards ultimate success. There is a lot of helpful technical advice that can be given in individual cases by the veterinarian, but there is no set procedure such as S.19 for abortion or crystal violet vaccine for swine fever that can be recommended by the N.A.A.S. The latter Service, however, can make a most important contribution by pointing out the difficulties of controlling this disease, and the need for non-concealment and co-operative investigational effort if success in mastering it is to be achieved.

Mechanization and Management

C. CULPIN

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ONE of the most important points of difference between farming of the 1930s and that of today is the almost complete dependence of today's farming on successful mechanization. The change is naturally most marked in mainly arable areas, where even after allowing for the great change in the value of money, mechanization costs are today about two-and-a-half times what they were in the middle 1930s [1]. Even on mixed and stock farms where grass is really cultivated, the situation is roughly similar, for tractors and equipment for green fodder conservation are now usually indispensable. Yet this revolution in farming which has been brought about by the use of power and machinery during the last twenty years has taken place with so little fuss that there is sometimes a tendency for even farmers themselves to fail to appreciate its extent and significance. It is true that there are now few farmers who parade their lack of knowledge of machinery as if it were a virtue; but it is still possible to find a few who regard machinery problems as something that can be left to the wisdom and discretion of a particular agricultural machinery dealer, or to the skill of a good mechanic. Moreover, there are universities where farm mechanization is regarded as a subject which cannot profitably be studied in agricultural degree courses—and well-meaning individuals who think that a study of mechanization should be discouraged, since it could lead to still more expenditure on machinery.

Most progressive farmers have little doubt about what machinery means to them, and now appreciate the fact that effective planning can often reduce the amount spent on labour and machinery on a particular farm. Mechanization must, of course, be considered in relation to all other relevant management factors, particularly labour. Any significant change in production plans involves labour and machinery to a greater or lesser extent, and very often *providing* the means of doing the new job is such an important factor in deciding success or failure that it would be folly to re-plan without at the same time considering very fully the labour and machinery aspects.

Labour and Machinery Costs

The scope for securing substantial economies in mechanization is shown both by the national figures which are issued at the time of the price reviews, and also by those published from time to time by Provincial Agricultural Economists. Recent figures show that on average, the cost

of farming is made up as follows:

	National Figures 1956-7 White Paper Forecast		Eastern Arable Area Figures (1956)	
	per cent		*per cent*	
Labour	25	42	28	48
Machinery	17		20	
Feedingstuffs	31		20	
Fertilizers	7		—	
Seeds and Fertilizers	—		14	
Rent	—		5	
Rent and Interest	7		—	
Other	13		13	

Measures of Mechanization Efficiency

Machinery and *labour* costs need to be considered together: the sum represents about half of the total cost of farming. Sturrock, who has frequently pointed out the outstanding importance of mechanization progress in East Anglia, has recently published "standards" by which mechanization efficiency can be assessed [2]. One of the most important indices is the net output per £100 labour and machinery. The figures quoted range from £150 for a small mixed farm ("average" standard) up to £235 ("premium" standard) for a large farm growing mainly cereals. Ratios on the most profitable farms may be as high as 3:1.

Where a low profit is associated on a particular farm with a low output per £100 labour and machinery costs there is obviously likely to be something wrong with either labour or machinery management, and it is then useful to compare equipment and methods with those used on more successful farms of a similar type. The remedies are not always obvious. It is no use merely to tell a farmer "You should reduce your machinery expenses" or "You ought to cut down your labour". Only too often, simply getting rid of some machinery or men in such circumstances would merely lead to disaster. Nothing less will suffice than a thorough study of both labour and machinery in relation to all the main jobs that have to be done throughout the farming year.

At this point the help of a specialist adviser who spends his whole time on farm mechanization problems can be a great help. All too often the farmer is over-influenced by tradition in his management of men and machines: moreover, if the situation calls for any substantial re-equipment, it is essential, before a decision is made, to know the likely future trends as well as the machines available at the time.

Sometimes when output is low in relation to machinery costs a high proportion of the cost may be due to heavy depreciation charges on a few expensive and little-used items such as a combine harvester, pick-up baler or grain drier. The farmer may have spent £1,800 on a diesel-engined self-propelled combine harvester where a p-t-o driven trailed machine costing less than half as much would have served as well.

Sometimes in such circumstances it is not worth while to try to sell the expensive machine—but the moral should be drawn about taking much more care in future. Farmers can hardly expect the supplier to be completely uninfluenced by commercial considerations in his advice on such a matter—and there are now very few agents who are not associated with one or more manufacturers exclusively. Moreover, it is easy in such circumstances to argue that spare combine harvester capacity is a substantial asset. Clearly every farmer has to decide for himself how much such spare capacity can be allowed to cost.

The whole essence of successful management through good mechanization is obviously regular and thorough forward planning of machinery programmes, rather than a series of hurried salvaging operations. The plan should be based, wherever practicable, on equipment which can be relied upon to be still serviceable and useful many years after purchase, and this usually means sticking to firms of good standing. Such a plan ensures that no machine is ever bought without considering in full detail the effects of its introduction on the farm work and on the finances. Obviously, it is essential to standardize on one or two types of tractor as far as practicable, and to avoid changes that seem desirable merely because of some relatively unimportant technical improvement.

Value of Method Study

Many farming operations such as farmyard manure carting and spreading, silage-making, potato harvesting, etc. can be carried out in a wide variety of ways. Some of the methods available call for large gangs and are clearly unsuited to small farms, but some machines such as hydraulic front loaders are suitable for use on both large and small farms provided that the system of operation is adjusted to suit. Often a small gang and a little equipment give better results than a large gang and a great deal of equipment, even on large farms. A good deal of useful information has been accumulated from carefully conducted method studies on individual farms, and it is now well worth while for a farmer to consider the results of these investigations *before* ordering new equipment. Studies carried out by N.A.A.S. Machinery Advisers showed that one man was as efficient as a gang at farmyard manure loading and spreading —and the only equipment needed was one tractor with front loader and an easily hitched trailer-type spreader. Similarly, with silage-making, it was found that gangs of two men could work very efficiently with a forage harvester, provided that a simple two-wheeled bogie was used to facilitate changing of the towed trailers. In both of the above cases, however, the use of a tractor with a hydraulically-operated pick-up type trailer hitch is pre-supposed, and in future similar devices will become essential for efficient labour utilization on both large and small farms. There are, of course, circumstances on large farms where a very high output is needed and fairly large gangs are called for. Even then,

however, there is seldom much to be gained by having a gang of more than half-a-dozen men, and where larger gangs are employed it is worth while studying the job in some detail to decide whether the same or almost the same result could be achieved with fewer men and machines. There can be no doubt that such method studies, leading as they can to the use of smaller gangs and fewer specialized machines, can go a long way towards making farm mechanization in Britain more efficient.

In a similar way, it pays to make a very thorough study of possible methods and equipment before buying and installing equipment such as grain driers, feed grinding and crushing mills, and feed mixers. There is now such a wide variety in shapes and sizes of equipment and in what they can do in the way of handling materials that it is essential to consider all of the likely methods. With new types of equipment complex operations can be done much more simply than a few years ago, and the whole installation needs to be planned according to sensible materials-handling principles.

Value and Limitations of Partial Budgeting

When a particular mechanized operation is being considered, the technique of "partial budgeting" may be applied with advantage, to determine the economic effects of employing different methods. This is always a useful exercise, if only because it helps to make the farmer get used to thinking of his "fixed costs" as well as the running costs. Any such technique can, of course, be dangerously misleading if applied with too much regard for the arithmetic and too little for such practical considerations as:

1. the real extent of the *need* for labour saving;
2. technical suitability of the machines available, and
3. the technical competence of the individual farmer and his men in handling the equipment under consideration.

These reservations are best explained by a simple example, such as the problem of what to do about silage-making machinery when a green crop loader hitherto used for collection becomes too worn out to justify further repair. Let us suppose that the need is, and is likely to remain, to make 200 tons of silage annually. If a pick-up baler is already on the farm an ideal solution, in theory, is to use this for silage-making. This may also be a good practical solution, but on the other hand, there could be a good case for using a simple forage harvester costing say £350. The partial budget will show a substantially lower total cost for the baler method, in spite of higher labour costs; and it will need a very careful comparison of operating systems, quality of silage, ease of feeding, etc. before a sound decision can be made.

Repercussions of Mechanization Changes

No substantial change in mechanization policy can be considered in isolation. Quite apart from the direct effects on labour utilization and availability, new equipment often provides the means of increasing farm output if the overall production plan can be suitably adjusted. For example, the mechanical sugar beet harvester may make it a fairly simple matter to increase sugar beet acreage on some farms, but before this is done (quite apart from the question of a contract) the effect on another period of peak labour need—viz., the time of thinning the crop—must be considered. A mechanical thinner may have to be considered, and it is necessary then to study such technical questions as whether the seed beds are likely to be suitable, whether the standard of workmanship with this type of equipment is likely to be high enough, and whether there is likely to be any substantial reduction in yield. Then there is the question of whether the mechanically thinned crop can be efficiently harvested by a particular type of harvester. A mechanization change will very often have far reaching effects; for instance, introducing a more efficient milking parlour could lead to an increase in the size of the dairy herd, and the further repercussions that such a step would involve.

Need for Simple Labour Records

One of the essentials for long-term mechanization planning is some method of keeping simple labour records which readily show up the overall results and the chief problems. The records should make it possible to prepare a chart showing:

1. total man hours of labour used in each week of the year, and
2. approximately how the total is made up (e.g., regular work on stock; casual work; and work by the regular staff on the various crops).

Such knowledge provides a valuable guide when trying to decide how to get over a particular difficulty, such as a clash between sugar beet hoeing and haymaking.

Replacement or Repair

There are some mechanization problems which cannot be settled by any set of rules, but can only be decided by the farmer himself, in the light of his individual preferences and capabilities. For example, a farmer who has no knowledge of repair methods may always endeavour to keep a good set of tackle by the simple expedient of selling his slightly worn machines and buying new ones, while another who knows practically all there is to know about repairs will hardly ever buy a new machine, and prefers to spend a great deal on keeping the old ones in good order. Both could be right in their particular circumstances, but both policies carried to extremes can be unsatisfactory.

There is little to choose between the two extremes of policy as regards income tax, since both depreciation allowances and all repair costs can be deducted as expenses. No set of rules can therefore be laid down on this subject; but it is certain that a comprehensive workshop employing a full-time mechanic can be an unjustified expense on a small farm, whereas it can often be a very valuable asset on a larger one.

Looking Ahead

There can be little doubt that labour is going to become scarcer, and every possibility that it will cost more. Compared with countries like the United States and New Zealand, we still hardly know the meaning of a real labour shortage in farming. There can be no doubt about how the future will have to be tackled: more and more unnecessary hand work will have to be eliminated, and jobs that have hitherto been done by hand either got rid of or done with the help of a machine. The best and most efficient mechanization is usually the simplest, and a great deal of thought will surely have to be devoted to simplifying fodder conservation and stock feeding work. One of the greatest needs is for farmers generally to become more positively conscious of the need to plan their mechanization very much in the same way as they plan rotations. There should be a long-term plan, which is carefully reviewed annually and modified as necessary in the light of any important new developments.

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Typical Romney Marsh Scene. *Douglas Weaver*

PLATE I

Kent Messenger

Royal Military Canal with Romney Marsh on the right.

Douglas Weaver

Winter Feeding.

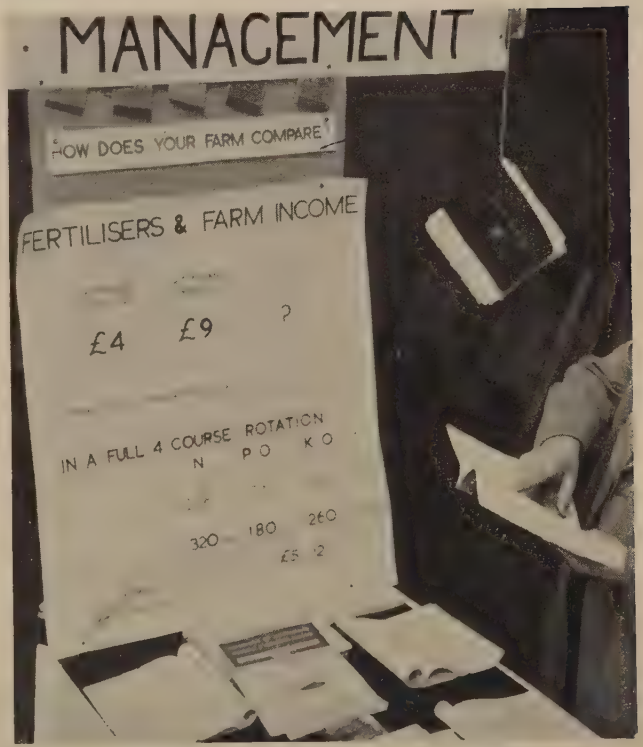
Douglas Weaver

Romney Marsh Breeders' Annual Show.

Douglas Weaver

Champion Romney Marsh Ram.

Exhibits are seldom completely self-explanatory; Advisory Leaflets add important information.



Sometimes a priced bulletin is appropriate, but selling distracts the adviser.

PLATE IV

Review

Milk By-Products for Animal Feeding

MILK PRODUCTION in the United Kingdom far exceeds the amount used as liquid, and each year a larger proportion has to be diverted to manufacture. The following table, derived from official statistics [1], shows the position in the last two complete calendar years.

Sales of Milk through U.K. Milk Marketing Schemes

Millions of gallons

	Liquid Consumption		Manufactured	
	1956	*1957*	*1956*	*1957*
January-March . . .	381.9	372.4	114.0	137.1
April-June	381.9	376.6	227.5	262.4
July-September . . .	374.5	373.0	138.6	160.9
October-December . .	382.5	381.0	129.1	135.4
	1520.8	1503.0	609.2	695.8

These figures do not represent all the milk produced on the farm but only that recorded by the Marketing Schemes; total production is therefore even greater. The liquid consumption corresponds roughly to 0.7 pint per day per head of population. Although the production of marketed milk as recorded above increased by about 69 million gallons from 1956 to 1957, there was a fall of about 18 million in liquid consumption, and therefore 87 million more gallons had to be passed for processing into condensed or dried whole milk, butter and cheese. The many millions of gallons used in making the two latter commodities produced in turn vast quantities of skim milk, buttermilk, and whey, and it would seem that this flood of valuable by-products is likely to pour forth for a long time to come. It is essential that full use be made of these by-products as they are rich in first-quality protein, milk sugar, minerals and certain important vitamins. Some of it is condensed or dried, but this is less attractive than similar processing of whole milk because of high costs and the lower value of the products. There is an urgent need to use them in liquid form as much as possible.

For very many years the Continent has shown the way. Amongst other countries, Denmark, France, Germany, Holland and Sweden have used many times the volume of liquid by-products for livestock than is used in this country. In Sweden, for example, 70 per cent of the skim is returned to the farms for pig feeding [2] and the average quantity fed daily per pig is 4½ lb, the range being 3½ to 8 lb.

In New Zealand, the amount of skim milk produced in the butter-making season can be an acute embarrassment and pigs are used to scavenge it [3]. Pigs receiving nothing but milk are expected to dispose comfortably of 1.75 gal at 41-45 lb live weight and 3.40 gal at 100 lb. In one trial the average daily intake per pig weighing between 51 and 110 lb was 2.84 gal and live weight gain per day was 1.05, the consumption per 1 lb gain being 2.69 gal. This did not represent the maximum possible intake. Pigs on *ad lib.* feeding averaged 3.26 gal over the same range, but the milk conversion was not quite so efficient. It is considered that the most efficient rate of feeding skim milk as the sole food is given by: $(3.5 \text{ to } 4.0 \times \frac{\text{live weight in lb}}{100 \text{ lb}})$ gal per day over the range 40 to 80 lb live weight. For example, this would mean 1.75 to 2.0 gal for a 50 lb pig. Smaller intakes were preferable over the 80-100 lb range to discourage overfat carcasses. Feeding at such rates would not be economical at the prices obtaining at present in this country, but it at least demonstrates what is physiologically possible.

Composition of Liquid and Dried By-products

Milk of good quality (say, 3.8 per cent fat and 8.8 per cent solids-not-fat) could give products with approximately the following proportions of the major constituents:

	Fat	Protein	Sugar, etc.	Minerals	Total
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Skim milk* . .	0.1	3.6	4.9	0.8	9.4
Buttermilk . .	0.5	3.5	3.9 (plus 0.6 lactic acid)	0.7	9.2
Whey . . .	0.3	0.9	4.8	0.6	6.6
Dried skim milk .	1	37	51	8	97
Dried buttermilk .	5	35	46	7†	93
Dried whey . .	4	13	70	9	96

*Here and elsewhere in this Review, "skim" and "separated" are treated as synonymous and "skim" is alone used throughout.

†This figure may be higher if alkalies are used to neutralize acidity.

It will be seen that skim and buttermilk are for all practical purposes of equal feeding value and this is true also when the minor constituents such as vitamins are taken into consideration. (This assumes that the buttermilk has not had wash-water added to it.) It is also permissible to regard dried skim milk and dried buttermilk as of equal value; and, further, one may say that from the nutritional viewpoint 1 gallon of either liquid product is equivalent to 1 lb of either dried product. Thus, if a gallon of skim costs 4¾d., a pound of dried skim is worth the same and

a ton of dried skim is worth £44 6s. 8d. In view of the *actual* price of dried skim it is well worth while using as much of the liquid product as possible for all stock requiring milk. It is perhaps better to assume that whey has about one-third of the value of skim milk in British practice, although this estimate may prove to be rather conservative.

Whey is somewhat different. So much valuable protein has been removed in the cheese curd that only one-quarter remains and the total solids are only two-thirds of those of skim and buttermilk. The proportions of the major ingredients to each other are much the same as in a cereal, but the high quality of the protein, the complete digestibility, and the valuable vitamins put it in a super-class. It is not easy to compare it fairly with the other by-products, but Morrison [4] suggests that for pigs it is worth half as much as skim milk.

Whereas the drying of skim and buttermilk involves a tenfold concentration of solids, that of whey concentrates the solids 14 or 15 times. Thus, dried whey contains one-and-a-half times as much vitamin as dried skim milk and this makes it particularly valuable in the opinion of poultry-keepers, especially in the U.S.A. It is common practice there to manufacture an even richer "whey product" by crystallizing out part of the lactose during evaporation prior to drying. By the reduction of the lactose from 70 to 55 per cent or so, all the other constituents are correspondingly increased. Fortified dried whey contains extra riboflavin by fermentation. Instead of complete drying, whey is sometimes condensed to about 60 per cent or more of solids. One feature to be guarded against is excessive saltiness; this may arise from the inclusion of whey draining from cheese curd after the salting process. If necessary, whey can be de-salted. One case is reported from Sweden [5] where the addition of saltpetre to the cheese-milk gave rise to nitrite in the whey and this caused toxic effects in pigs. Such an eventuality is not likely to arise in British manufacture.

Preservation of Liquid By-products

Stock do best if the skim milk is fed always in the same condition, either always fresh or always sour. If the condition is variable digestive upsets and scouring may occur. Deliveries from factories to farms may have to take place at intervals of several days and the milk may have to be stored on the farm for some time. This may mean that the milk may turn sour in summer before it can be completely used. To meet the situation it has been suggested that milk should be allowed to sour before it is used. This process has the disadvantage that the rate of natural souring may be variable according to day-to-day temperatures and hence controlled souring has sometimes been adopted. There is the further disadvantage that soured milk is difficult to convey by pipe-line and the vessels containing it are more troublesome to clean. Accordingly, attention has been given more recently to suitable preservatives for maintaining it in a fresh condition.

The problem is one which in practice affects skim milk rather than whey or buttermilk. The value of whey does not often justify carriage for long distances and it is best used locally or processed; in any case, lactic acidity has already been developed in it. Buttermilk is also rather acid but there is the further point that much less of this is available than of skim milk. For every unit weight of butter produced, the volume of skim is about twenty times that of buttermilk (undiluted by washings) according to the richness of the original milk. Buttermilk is therefore a comparatively minor by-product and it is usually added to the skim milk. Where the skim comes from cream manufacture, the question of buttermilk does not, of course, arise.

One suggestion [6] for the utilization of skim milk is to acidify it with hydrochloric acid and drain off the curd, which is then packed in wooden barrels. The average protein and dry matter contents of the curd were 24 and 30 per cent respectively when fresh, and 29 and 34 per cent after storage. The curd kept sufficiently well for two weeks and more, even in summer. Its nutritional value was estimated at less than half that of fishmeal and manufacturing costs were reckoned at something under 1*d.* per gal of which 0.15*d.* represented the cost of the acid. The disadvantage of this process is that all the nutrients of the whey are lost.

CONTROLLED SOURING

Continental workers have adopted various methods of controlled souring whereby all the food value of the milk is retained. The aim has been to develop acidity by lactic organisms or to confer it by the addition of organic acids which are harmless to stock in the quantities used. Both methods discourage the development of putrefactive organisms. The attainment of sufficient lactic acidity quickly enough to suppress putrefying organisms requires a heavy inoculation with starter, but on the other hand the necessary pH of 5.5 to 5.7 is immediately obtained by the addition of 1 vol. of 15 per cent acetic acid to 100 vol. of the skim milk [7], and automatic addition is possible by the Silkeborg apparatus. Acetic milk was tested against lactic milk as a food for calves. Calves given whole milk until three weeks and then gradually changed over to one or other of the acidified skim milks during the next three weeks continued to receive the acidified milks plus concentrates, hay, roots, and pasture until six months old. The average total intakes were about 22 gal of whole milk and 220 gal of acidified skim. There was no difference in size, weight or health between those which had received acetic and those which had received lactic skim. Coliforms and salmonellae were inhibited in both the acidified milks. Formic acid has also been used [8] as an acidifying agent and the results have been satisfactory.

PRESERVATION

Preservatives to prevent souring have been investigated mainly in two instances: hydrogen peroxide and formalin (a solution containing 40

parts of formaldehyde per 100 parts). The use of the second seems likely to become a standard practice in this country.

Hydrogen peroxide of 130 vol. strength has been used at the rate of 2 parts per 1,000 parts of skim milk [9] and milk preserved in this way successfully replaced fresh skim in a 60-day trial with calves. However, in a review [10] of the use of peroxide as a preservative, it is stressed that every trace of peroxide should be removed from milk which might be used for human consumption in view of the possibility of hydrogen peroxide having some carcinogenic effect.

Formalin, at the prescribed rate of 1 vol. per 1,000 vol. of skim (0.1 per cent), costs only a fraction of either acetic, formic or peroxide. It is also preferable to the acids in that it maintains the original state of the milk and it does this more efficiently than peroxide. It is the additive of choice at the present time, and the one consideration still under observation is whether or not it is completely safe for all classes of stock. It has proved to be harmless for weaned pigs, but official publications [11, 12] are still cautious about advising its use for sows and sucking pigs, and for calves, until more experience has been collected. A report from one farm [13] states that observations made over 18 months show that sows and their litters can be fed safely on formolized skim. Also, calves given whole milk for only 3 weeks have shown average liveweight increases of almost 2 lb per day over 6 months on a ration of 1½ gal formolized skim with cereals and added vitamins. The one precaution necessary was that the changeover from the whole-milk diet should be spread over a fortnight or more. Attempts to change to the formolized skim milk in a mere 2 or 3 days brought disaster.

A pioneer paper [14] describes initial trials with 0.5 per cent formalin, but it was found that this quantity tended to make pigs refuse the milk and when the work was extended to commercial farms the present standard of 0.1 per cent was adopted. The only other food necessary was a meal mixture of 3 parts barley to 1 of miller's offal with supplementary minerals and vitamins. A report of a farm's experience [15] states that the newly weaned pig was best able to consume its gallon of formolized milk if it were fed in four portions—with meal in the morning and afternoon and without meal at midday and in the evening.

Finally, it must be said that skim milk to be used in the liquid form for livestock should be free from disease organisms. In particular, if the farms supplying the factory are not all attested the milk must be pasteurized, and in any case such processing is a helpful factor in extending the keeping quality even when formalin is used.

Skim Milk, Liquid and Dried

FOR CALVES

Many papers on the use of skim for calves have appeared in recent years and to some extent recent advances in early weaning have made them obsolete. It is not now a question of replacing whole milk by skim but, in the opinion of some, of replacing any kind of milk by meal and

water as quickly as possible. However, it has to be remembered that the dry meals so used must contain some animal protein—fishmeal, or dried skim milk or both—and it may be equally or even more economical to supply this as liquid skim. Four lb of meal containing 10 per cent each of fishmeal and dried skim milk could have the value of its animal protein replaced by a little more than 1 gal of liquid skim milk. Where ample skim is available for all stock, it would be possible to use some of it for calves with a little cereal mixture plus Vitamins A and D and extra minerals. If a calf were receiving x lb of balanced meal plus water, this could be replaced by y gal of skim milk plus (x—y) lb of vitaminized, mineralized cereal; e.g.;

2 lb bal. meal = 1 gal skim + 1 lb supplemented cereal, or
4 „ „ „ = 1½ „ „ + 2¾ „ „ „ , or
4 „ „ „ = 1½ „ „ + 2½ „ „ „

A minimum of one gallon of milk is used for this scheme.

An Italian system [16] gives colostrum and whole milk for the first week, and in the second the whole is replaced by skim fortified with 100,000 i.u. Vitamin A and 25,000 i.u. Vitamin D. Partial replacement of the skim by hay and concentrates begins between the 10th and 13th weeks. (This is a long delay in introducing concentrates, and the large quantity of skim required in the absence of concentrates would not be economical with present British prices for skim and meals.) It was claimed that growth was more rapid than on whole milk and the method is said to save £10 per calf [17]. The vitaminized skim milk was required at the rate of 14 lb for 1 lb liveweight increase in bull calves and at 13 lb for heifers. The view that skim fortified with vitamins can even be better than whole milk was reiterated [18], following work with one-egg, twin heifer calves. It was suggested that whole milk might be ideal for calves active on pasture, but that it was unnecessarily rich for calves warmly housed indoors.

Successful reports of skim milk rearing come from the U.S.A. The use of whole milk for a month followed by skim gave no better results at 6 months with Holstein calves than did skim following 3 days on colostrum [19]; hay and cereal completed the ration. Jerseys did not do quite so well on the lower energy ration. A study [20] of the length of time for which skim milk feeding has to continue showed that calves changed from colostrum on to vitaminized skim and cereal (no high protein supplement) did sufficiently well whether the skim was discontinued after one month or after longer periods up to 6 months. In all cases sizes and weights were comparable with the Ragsdale standard.

In Germany [21] calves have been given colostrum for a week and then for the following 15 weeks have received varying proportions of whole to skim milk with or without antibiotics, and with hay and

concentrates *ad lib.* Satisfactory growth was obtained with a total of 5½ gal whole and 177 gal skim milk together with an aureomycin supplement.

As there is so much evidence of the value of skim milk when practically unaccompanied by whole milk, other papers [22, 23, 24] which record the use of appreciable amounts of whole milk have not been considered in detail; but some work has been reported [25] which shows a failure to rear calves successfully on milk containing less than 2 per cent fat, although more milk was given to compensate for loss of energy, vitamins (cod liver oil) were supplied, and hay and concentrates offered *ad lib.*

Skim has been used successfully for veal calves in Bavaria [26] and in Poland [27]. In the Bavarian work, the period of fattening was from the 2nd to the 10th week, and one set of bull calves during this time received an average per head of 147 gal whole milk, the average total liveweight gain being 149 lb/head and the daily gain 2.5 lb/head. A corresponding set received 43 gal of whole and 131 gal of skim (1 of whole to 3 of skim) over the same period, and showed average total and daily liveweight gains of 137 and 2.2 lb respectively. The carcasses of all calves were of good quality. The Polish workers found that calves could be fattened successfully on as little as 40 gal of whole milk given over 84 days with hay and high-quality concentrates and adequate skim milk. The restriction of whole milk did not adversely affect growth rate or carcass quality.

Useful practical advice on feeding skim milk to calves is available in pamphlet form [12].

Just as liquid skim has proved its usefulness, so also has dried skim milk. Guernsey bull calves were satisfactorily reared (after 3 days on colostrum) on reconstituted dried skim milk supplemented with 4,000 i.u. vitamin A, 500 i.u. vitamin D and 50 mg aureomycin per lb. The cost of feeding was cut by 35 per cent over 13 weeks [28a]. Further work [28b] with a Jersey bull and Friesian heifer calves showed slightly less gain than when whole milk was fed, nevertheless, the calves were thrifty. Other American work [29] showed that when no additional fat was supplied, 1.6 lb s-n-f per 100 lb live weight was required for satisfactory growth.

British work [30] has compared milk substitutes for the period from 4-20 days old prior to abrupt early weaning, colostrum being given for the first 3 days. Experience showed that for the Ayrshire calf a maximum of ¾ lb reconstituted dried skim milk or dried buttermilk per day proved adequate. Antibiotic was added to the milk, hay and water were offered *ad lib.* at one week old, and a meal mixture at two weeks.

FOR PIGS

The use of skim milk for pigs is so long established, as already mentioned, that there is little that is new to be reported. Excellent advice is available to British farmers in several pamphlets recently issued [11, 12, 31]. Its great virtue is that the meals that it supplements can be constructed of the cheaper cereal foods and much less high-protein food

need be purchased. Pigs under 8 weeks can be offered it *ad lib.*, and quantities can be varied from ½ or ¾ gal at weaning to ¾ or 1 gal at bacon weight. The meal allowance appropriate to the age, apart from being less rich in protein, can be reduced by ¼ lb for every ¼ gal of skim milk given. The usual precautions must be taken, of course, to provide the necessary vitamins and extra minerals (and antibiotics if desired).

The situation in New Zealand, where seasonal excesses of skim are fed to pigs sometimes requires that the pig be prepared beforehand by appropriate feeding so that it can use the milk with the maximum efficiency. Work on this [32a and b] has shown incidentally that 1 gal of skim milk is equivalent to 1 lb of a mixture in the proportions of 1 part of meat meal (60 per cent protein) to 3 parts barley.

Dried skim milk has been compared [33] with meat and bone scrap and with extracted soyabean meal when all were added to semi-purified diets. The other ingredients included maize starch, maize oil, dextrose, minerals, vitamins and antibiotics, and the overall protein in each of the rations was only about 11 per cent. Under these unusual conditions the dried skim milk was significantly better than the two other protein feedingstuffs.

A more practical study comparing dried skim milk with white fish meal has just been reported in Britain [34]. The basal ration was composed of barley, miller's offal, antibiotics, vitamins and (in the milk rations) enough bone flour to compensate for that of the fishmeal. When the proportion of dried milk was increased beyond 10 per cent the barley was correspondingly reduced. The main points are shown below:

Ration	Ration to 130 lb live weight		Ration from 130 lb live weight		Average overall daily gain (lb)	lb food for 1 lb liveweight gain
	Protein supplement as % of ration	% Crude Protein in ration	Protein supplement as % of ration	% Crude protein in ration		
1	10% F.M.	17.7	7% F.M.	15.5	1.47	3.16
2	10% D.S.M.	14.9	7% D.S.M.	13.5	1.42	3.20
3	15% D.S.M.	16.3	10½% D.S.M.	14.5	1.47	3.09
4	20% D.S.M.	17.7	14% D.S.M.	15.5	1.54	2.99

The daily gain on ration 4 was significantly better (at the 1 per cent level) than that on 2, and was almost significant at the 5 per cent level compared with rations 1 and 3. The food conversions showed significance at 1 per cent between 4 and 2 and at 5 per cent between 4 and 1. It was suggested that the higher energy value of the dried milk may have had some effect, and that the protein percentage in ration 2 may have been marginal for the weaning pig. The authors consider that further work is needed on the matter. Meanwhile it may be noted that the slight superiority of ration 4 is not commensurate with the increased cost. Taking the cost of the dried milk and the barley as roughly £70 and £20 per ton respectively, each 5 per cent increase in D.S.M. would add

£2 10s. to the price per ton of the mixture. With fishmeal also roughly £70, ration 1 would appear to be the most economical. This also underlines the advice to use milk in the cheaper liquid form.

German workers have carried out trials [35] on pigs from 10 weeks to bacon weight with diets in which skim milk was given liquid (fresh or sour) or dried (spray or roller). The dried milk was fed either dry or reconstituted. Fresh and sour liquid skims were best. Spray-dried was very slightly better than roller-dried milk, but reconstituted milk gave much better results than dry feeding. Another interesting angle on the relative virtues of liquid and dried skim milk.

FOR POULTRY

Once again all the necessary practical advice is available in pamphlet form [12]. For chicks under 1 week old it can be diluted with an equal volume of water and the mixture offered *ad lib.* in place of plain water. After 1 week it can be offered undiluted, the amounts being increased to 1½ gal for chicks, 2½ for growers and 3½–4 for layers per 100 birds per day. (The extra liquid requirements of laying birds can be supplied by water.) At these rates no other animal protein food need be included in the ration. The usual vitamin and mineral supplementation of the vegetable mashes is of course necessary.

Dried skim milk is mainly included as a source of riboflavin, and English workers have stated [36] that if adequate riboflavin is added dried milk may be omitted from chick rations. American opinion is that, unless best quality fishmeal is present plus adequate riboflavin, milk will improve any ration for poultry [4 and 37]. It should be noted that the inclusion of fishmeal is normal British practice and 5 per cent was present together with substantial additions of riboflavin in the rations used in the work quoted.

Buttermilk, Liquid and Dried

FOR CALVES

As already mentioned, buttermilk as such is not likely to be available here because it is usually included in the skim milk, but dried buttermilk has been used in Australia [38] and in New Zealand [39, 40 and 41].

The Australian method was to replace whole milk during the 2nd week of life with buttermilk reconstituted from 1 lb of powder and 1 gal of water. Prior to the change the calves (Jerseys) had received only 10 gal of whole milk. By the end of three weeks dried buttermilk, bran and pollard offered as a meal were being eaten along with a little hay. Other calves received whole milk for 3 weeks and thereafter reconstituted skim and buttermilk for another 3 weeks before being weaned on to dry food entirely.

In New Zealand, calves were given whole milk for 4 weeks, and then over the next 2 weeks a change was made to reconstituted buttermilk which was continued for a further 4 weeks. The calves were on good

pasture throughout. Feeding the reconstituted milk at 12½ per cent of the body weight gave better results than feeding at 10 per cent, but no difference could be ascribed to the fat content of the powders, one with 8 per cent fat being as satisfactory as one with 16 per cent [39]. Further work [40] showed that calves changed from whole milk after 3 weeks and fed mixes containing buttermilk had done very much better by 10 weeks on gruel made from the mixes than on the dry mixes themselves. The mixes were 4 parts dried buttermilk, 3 parts pollard and 3 parts maize meal or wheat meal. There was no difference due to the cereals, but gruel feeding (1 part mix to 3 of water) produced a gain of 42 lb, compared with 26 lb on dry feeding. This is interesting in view of the experience with dried skim milk already mentioned [35]. Finally, the use of reconstituted buttermilk after 3 days on colostrum was compared with whole milk feeding [41]. The difference in liveweight increase of 1.1 lb per week in favour of the whole milk was not significant.

FOR PIGS

Pigs weaned after 1 week were fed for 3 weeks on a mixture containing 65 per cent buttermilk powder, 10 per cent meatmeal, 17 per cent cereals and 8 per cent sugar with minerals, vitamins and antibiotics. At 4 weeks the ration was changed to 10 per cent buttermilk powder, 10 per cent meatmeal and 80 per cent barley with the usual supplements. Although they weighed less than suckled pigs up to 6 weeks, they later reached and exceeded the latter's weights [42].

FOR POULTRY

Although dried buttermilk is greatly favoured in American practice, some conflicting experiences have been reported regarding the condensed product. Condensed buttermilk failed to improve a broiler ration with 21 per cent protein and including lucerne, animal protein, soya bean, maize gluten and vitamin and mineral supplements, when added at the rate of either 10 or 20 per cent of the mash [43]. In one year, condensed buttermilk improved egg production but in the next year, when two trials were carried out, it was effective in one but not in the other [44]. In another instance [45] it was stated that egg yield and fertility were less than in a control group receiving no milk supplements.

Dried buttermilk was used at the rate of 8 and 4 per cent of a starting ration for turkey poults and the growth compared with that of the control ration [46]. The buttermilk rations were equally good, but both were superior to the control although this was satisfactory. All rations had a crude protein of 24 per cent and contained 2 mg of riboflavin per lb.

Whey, Liquid and Dried

At the present time British cheese factories appear to have established outlets for the utilization of their whey and it does not present the same problem as skim milk. The following sections indicate some uses of whey in stock-feeding. In general, it would appear from the literature that the

high lactose content of whey products may predispose to scouring [29, 52 and 54].

FOR CALVES

There was no difference in the efficiencies of an all-vegetable calf meal and one containing 5 per cent animal protein when both were supplemented with dried whey product [47]. In another trial [48] one set of calves was fed a mixture of equal parts of condensed whey (60 per cent solids) and soyabean meal. This was compared with skim milk, 1 lb of the mixture being used in place of 6 lb skim. The skim was given at 1 lb/10 lb liveweight up to 15 lb skim, hence the maximum of the mixture was $2\frac{1}{2}$ lb. Both sets received alfalfa hay and cereals. The result of the trial showed that 1 lb cereal grain plus 2 lb of the whey-soya mixture had the same feeding value as 11 lb of skim milk. Neither dried whey (5 per cent of a milk replacing ration) nor lactose (3.5 per cent of the ration) had any significant effect on calves fed up to 2 months old [49]. The basal all-vegetable milk replacer had 10 per cent of distillers' dried solubles with minerals, vitamins and antibiotics also added, and presumably was able to supply all necessary nutrients.

FOR PIGS

It has been stated [50] that skim milk can be wholly or in part replaced by whey if sufficient is given to maintain the protein level. A French suggestion [51] is $\frac{1}{2}$ gal of skim or $\frac{3}{4}$ gal of whey for a 40 lb pig rising to 1 gal of skim or 4 gal of whey for the 220 lb pig. At the heavier weight, the 1 gal of skim and the 4 gal of whey are supplying the same amount of protein.

Growth rates of pigs fed 2 lb meal plus condensed whey were similar to those on all-meal feeding, but with less meal the rates declined progressively, probably as a result of excess lactose and/or salt from the extra whey taken to satisfy appetite [52]. Pigs at pasture could take more whey without scouring than could housed pigs.

English workers [53] have used unrestricted whey for fattening pigs. With a basal ration of 3 lb of a sow and weaner meal, whey could be taken *ad lib.* at any stage of the fattening period. Even as little as 2 lb meal could be used provided it was after the 13th week, but 12 more days were then required to reach bacon weight. Whey consumption was between $3\frac{1}{4}$ and 4 gal per day, depending on the amount of meal given.

Dried whey product was used [54] at the rates of 4 per cent and 8 per cent of the ration from weaning to 75 lb. It was beneficial in a ration mainly of maize and soyameal, but if alfalfa meal was included the alfalfa itself conferred a similar benefit.

The value of 2 per cent dried whey as a vitamin source in pigs rations is a matter of conflicting opinions. Some workers [55] have found that together with a B_{12} supplement it increased efficiency, although neither was effective alone. Others found no such benefit [56]. The rations used by the first workers contained no alfalfa but those used by the second

had 5 per cent. No evidence was found by other workers [57] of an unidentified growth factor for pigs in a dried whey product.

Replacement of part of the maize, barley, rye and herring meal in a ration by 25 per cent of dried whey or 23 per cent of de-salted dried whey altered the conversion rate from 3.57 to 3.62 and 3.69 respectively [58].

FOR POULTRY

An attempt to replace dried buttermilk for growing chicks by dried whey, keeping the riboflavin and protein contents of the ration unaltered, showed that at least a small amount of buttermilk is necessary for growth, and that it could not be entirely replaced [59]. Levels of dried whey above 10 per cent of the ration resulted in oedema. Two or 4 per cent of dried whey added to an all-vegetable ration improved the growth of chicks in their first 6 weeks [60]. Further additions of whey did not improve the results. Fishmeal was more effective than dried whey and was considered to have an additional factor.

Dried whey, to the extent of 3-5 per cent in a maize and soya ration (containing also 3 per cent alfalfa and vitamins) increased the weight gains of chicks in 4 experiments, each with between five and seven groups of 280 birds [61]. This increase was found even when antibiotics and APF (animal protein factor) were present. Lactose by itself was ineffective and therefore was not the responsible factor.

In rations for pullets, 4 per cent dried whey favoured growth and egg production when added to a purified diet, but hatchability was not normal and presumably the whey lacked a factor for this [62].

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S.M.B.

Regional Notes

Sheep on the Romney Marsh

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National Agricultural Advisory Service, South-Eastern Region

IN 1786, the Reverend Daniel Jones of New Romney, Kent, writing to his brother near Lampeter, Cardiganshire, said:

> *I mean to give you a short account of this Marsh, and of the method of grazing practised here as far as I am able to collect, leaving it to you to make such reflections and applications from the narrative as you shall think proper in anything that may suit your purpose, with regard to the management of your own stock.*
>
> *The land in general is rich but in different degrees; it is chiefly in pasture and is stocked almost entirely with sheep.*
>
> *So late as about thirty years back they suffered the grass to grow long and rank, thinking they could never have too much grass for their stock which thereby harboured the dews, and rendered the place aguish and unhealthy; but now, they find that sheep do not require a long bite; they have found by experience that they do not thrive so well upon coarse long grass; that they do much better by nipping it as it springs.*

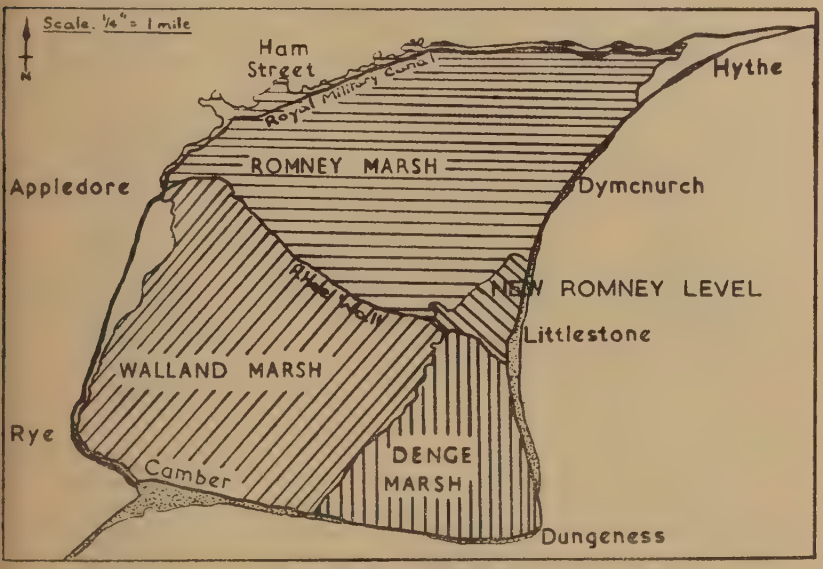
The full text of the Reverend Jones' letter [1] provides a description of sheep husbandry and general farming conditions on the Romney Marsh which varied but little in the succeeding 150 years, although the fame of the Marsh pastures and the Romney breed of sheep has spread throughout the world. Much has been written about this relatively small area tucked away in the south-east corner of England, and from the thirteenth century onwards, there are numerous references in literature to its sheep, wool trade, reclamation and drainage and, at times, a thriving trade in smuggled goods.

The Marsh Today

For the present article the description "Romney Marsh" is applied to the area which was the subject of the Romney Marsh Investigation Report [2] of the Agricultural Land Commission, and covers about 59,000 acres in Kent and East Sussex, bounded on the north by the Royal Military Canal, on the west by the River Rother, and on the south by the sea from Hythe to Rye—some 50,000 acres are agricultural land, about 42,000 acres of which are in Kent and 8,000 acres in East Sussex. The Romney Marsh proper refers only to the portion lying east of the Rhee Wall.

The general impression of the Marsh at first sight is of a wide, level plain, with scarcely a tree in sight and very few hedges. On closer inspection, however, most interesting variations are revealed, and quite a casual survey will reveal marked differences in the appearance of the pastures in adjoining marshes.

Most of the area lies below high-tide mark, and near Appledore on the north or landward side of the Marsh, it is 10-11 ft below sea level. Although each marsh varies in height by a few feet only, these differences have a marked effect on the grass and arable crops because of variations in natural drainage. The area is drained by a network of watercourses most of which discharge into the Royal Military Canal by pumping or gravity. The drains also act as "wet fences" for stock and are frequently maintained at artificial levels for that purpose. Rainfall averages about 25 in. per annum.



The Romney Marsh

A quick tour through the Marsh leaves the impression that the husbandry practised on the 600 farms is very uniform, and the visitor is always impressed by the great numbers of sheep seen in any part of the Marsh. Although sheep grazing is the predominant enterprise, a closer survey reveals quite a substantial element of arable farming. Cereals, potatoes and peas are the main arable crops and, under conditions of good husbandry, crops of over 2 tons of wheat per acre or 15 tons of ware potatoes, are quite common.

In recent years, the range of arable crops has increased, notably tulips and narcissi grown for bulbs, asparagus and farm and market garden seed crops. There is little dairying except near the coastal towns, but within the past ten years there has been an increase in the number of beef cattle.

The Sheep and the Swards

The sheep population has been the subject of considerable variation as the following table shows:

Agricultural Statistics of Crops and Livestock for Thirteen Parishes wholly within the Romney Marsh Area

Year	Tillage	Temporary Grass	Permanent Grass	Rough Grazing	Total Area	Cattle	Sheep
	acres	*acres*	*acres*	*acres*	*acres*		
1866	5,776	711	31,606	—	38.093	1,104	77,168
1870	7,049	472	32,101	—	39,622	1,974	169,960
1881	8,159	1,036	31,971	—	41,166	2,660	172,922
1891	7,819	1,454	33,739	—	43,012	2,838	179,633
1901	6,214	841	33,340	1,845	42,240	2,163	150,401
1911	6,520	767	32,035	2,401	41,723	3,626	165,156
1918	8,018	1,100	30,600	3,366	43,084	3,431	137,196
1921	7,313	1,175	28,834	2,546	39,868	3,256	129,229
1931	2,824	590	32,917	3,145	39,476	3,849	160,057
1939	3,892	765	35,178	3,767	43,602	3,739	178,176
1944	14,141	2,174	21,085	974	38,374	3,509	99,990
1948	13,884	3,654	21,629	1,652	40,819	5,748	98,713
1952	13,363	4.014	21,315	1,861	40,553	4,718	114,113
1956	13,355	4,322	19,405	1,915	38,997	4,259	132,751

The figures given relate to 13 parishes lying wholly within the Marsh area and cover an area of 40,000 acres. There are, however, a further 10 parishes which are partly within the area. For example, in the Table above, the sheep population in 1948 is recorded as 98,713, but for the whole marsh was 111,191. The summer density is approximately 5.2 sheep per acre over the whole of the grassland in June, but in winter is only about one-third of that figure. The carrying capacity of individual marshes, however, varies very considerably, but it is not uncommon for the stocking to be from 10 to 16 sheep per acre on many of the best marshes during the summer months.

Grass swards in the Marsh have been the subject of much discussion and the graziers take great pride in maintaining their best pastures in near-perfect condition. Four distinct grades of pasture are recognized [3].

Grade I—Fatting Pastures. These occur on the most productive soils and regularly fatten from 6 to 10 sheep per acre.

Grade II—Breeding Pastures. On soils slightly inferior and are of heavier texture than the fatting pastures and carry from 4 to 6 sheep in good store condition during the summer.

Grade III—Breeding Pastures. On still poorer soils which may be too heavy or too light, and liable to effects of drought. Such pastures have a carrying capacity of only 2 to 4 sheep in summer.

Grade IV—Rough Grazing Land. Usually in the shallow, sandy or shingle soils and has low sheep-carrying capacity.

Distribution of the various grades of pasture is reasonably uniform throughout the whole area, and although the best pastures are found on the deep, retentive, well-drained soils, there can be no doubt that centuries of careful management of stocking has contributed to their present high state of fertility. So careful is the management that often the visitor is left in doubt as to whether the grass is kept for the benefit of the sheep, or the sheep for the benefit of the grass!

On the best pastures, stocking is strictly regulated according to the height of the sward, and should it exceed about 1½-2 in., sheep will be drafted in from the poorer grades of pasture to maintain a very close sward. Should it become too bare some stock is removed. In recent years, rather than move stock the gang mower has been increasingly used to regulate the pastures.

The botanical composition [4] of the sward varies with the grade of pasture, and the best fatting pastures average 74 per cent Kent perennial ryegrass, 9 per cent Kent wild white clover, 8 per cent agrostis and 4 per cent each of rough-stalked meadow grass and Yorkshire fog. Generally, as the percentage of ryegrass decreases, the grade of pasture is lowered. Normally, growth starts in April and ends in October with a check in July in dry seasons.

In 1940, when invasion of this country seemed imminent, a decision was taken to prepare the greater part of the Romney Marsh for flooding and some 85,000 sheep were evacuated to the Home and Midland counties. This about halved the total stock but coincided with the war-time ploughing-up campaign; fortunately, sound common sense prevailed and few of the best pastures were ploughed out.

Although there is evidence that the sheep-carrying capacity of good leys is as great as the old pastures, few of the occupiers are prepared to sacrifice the best swards and bring them into a ley farming system.

The Predominant Breed

The predominant breed is, of course, the Kent or Romney Marsh which is extremely hardy and has no doubt developed throughout the centuries its characteristics of hardiness, freedom from disease and ability to maintain itself without artificial feeding and yield a good crop of wool.

The breed has also the useful characteristics of grazing extensively and of even distribution over the pastures. Under present market conditions, however, the breed has some serious defects. Firstly, the average crop of lambs born is only 108 to 120 per 100 ewes. Secondly, they are too slow in maturing to meet the demand for the small carcass. Thirdly, the older sheep, when ready for the fat market, is too large.

Considerable success has resulted from attempts to improve the fecundity of the breed which were made over many years by selecting twins for breeding on both male and female sides. Percentages of up to 160 were obtained in some years, but surprisingly few flock-masters have followed this lead. The introduction of other breeds and crosses has been tried, but although the crosses—particularly that of the Southdown Ram on the Kent ewe—produce an early-maturing lamb, none of these breeds or crosses has proved sufficiently hardy as breeding flocks to stand up to the rigours of climate or the type of management provided.

Management

Flock management is fairly uniform over the area and is dictated by soil, drainage and climatic factors, although there is evidence that tradition also plays its part. The rams are put to the ewes in early November without any flushing of the ewes, and no extra food is given during the winter except in extremely hard weather. The lambing season, early April, is frequently accompanied by spells of bitter east and north winds, but the ewes are kept in the open with only a few straw hurdles for protection. In May the growth of grass gains on the ewes and lambs but, at this time, the sheep, which have been wintered on the upland, are returned to the Marsh. The ewes and lambs are usually kept on the lower grade pastures throughout the summer and, in the autumn, when the grass begins to fail, some of the lambs are sold in Ashford or at other local sales, and the remainder moved to higher ground in Kent or the Home counties or even further afield. The ewes remain on the Marsh with the wether tegs and some lambs.

Movement of the lambs to upland pastures and the cost of agistment is an expensive item, but no other system has yet been evolved to overcome the necessity of reducing the stocking on the Marsh in winter. When these sheep return to the Marsh in the following May, most of the wethers are fattened off during the summer.

Some wethers, however, which return to the Marsh in poor condition are kept on for a further year and sold off fat at over 2 years old, making a big, overfat sheep with no place in the present-day meat trade. Thus, on many farms in summer there are four groups of sheep: the breeding ewes, lambs, one-year tegs and two-year wether tegs. This practice is rapidly dying out, however, and by better treatment, more lambs are now sold fat and the remainder fattened off in the next year.

In spite of the high density of stocking and the continuous grazing to which the pastures are subjected, the general health of the flocks is remarkably good. With good management and shepherding and by using modern vaccines and drenches troubles such as parasitic worms, pulpy kidney and "struck"* can now be controlled and losses are rarely serious. Twin lamb disease is usually less common in Marsh flocks than in upland flocks.

In recent years, new handling pens have been erected, the designs being mainly on New Zealand systems adapted to local conditions. Several demonstrations have been held on new methods of sheep handling and, in spite of a strong leaning towards traditional ways, new ideas are rapidly gaining ground, particularly when the shepherds are convinced of the big reduction in manual labour involved.

The wool crop is estimated to represent about 23 per cent of the total income from sheep and Romney wool finds a ready market, the average yield of wool from ewes being 7 to 8 lb, although some flocks will average over 9 lb per fleece. The average wool crop from teg is from $5\frac{1}{2}$ to 7 lb, and it is general practice to shear the lambs which yield from 1 to $1\frac{1}{2}$ lb per head.

The Romney sheep has always been in great demand overseas because of its hardiness and ability to adjust itself to changes in climate. The export trade is handled by the Kent or Romney Marsh Sheep Breeders' Association which was founded in 1895 and, since that time, about 20,000 rams and 10,000 ewes have been exported to the Argentine, Chile, Poland, South Africa, New Zealand, Australia, Uruguay, Brazil, Canada, Russia and many other countries in smaller numbers. In New Zealand, the Kent or Romney blood predominates although types have been selected for lighter carcass weight, earlier maturity and denser fleece.

Recent Changes

During the past six years, the balance between sheep, cattle and arable appears to have reached a state of equilibrium and approximates very closely to the recommendation made by the Agricultural Land Commission in the Romney Marsh Investigation Report [2]. A number of intensive arable farmers settled in the Marsh after the war, and the tendency was to dispense with sheep flocks on these farms. Most of them, however, have now succumbed to the Romney Marsh tradition and they have very successfully re-introduced sheep on leys.

The outstanding problem of the present day is to find the best means of meeting the demand of the market for young lambs and small carcasses. Both breed and system of management are not well adapted to meet modern requirements, but most flockmasters are endeavouring to market earlier, and they are reasonably satisfied with the prices obtained. There is still much room for improvement. Better treatment of the ewes

*A local name for entero-toxaemia, produced by *Clostridium welchii* type C.

at mating time would help to increase the lamb crop. The selection of ewes for better milking and mothering would enable twin lambs to be finished earlier, and at the same time, selection of breeding stock from twins could raise the lamb crop substantially.

In conclusion, I again quote from the Reverend Jones' letter of 1786 :

> *But it must be observed that it is not everyone who is capable of being a good Grazier as their business is to make the most they can of their grass, it requires a man of sense and judgment to do that to most advantage whether we consider it with respect to the grazing of their land or to bring their stock to market with the quickest return and greatest profit.*

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Evaluating Advisory Work from Leaflet Consumption

Experiences on a Corn Exchange Stand

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HOW USEFUL can a market stand be in advisory work? We have been staging a weekly advisory exhibit at our stand in Lincoln Corn Exchange since 1950, and refer readers to No. 24 of this REVIEW, Summer 1954, for a description of the Exchange and of the type of exhibit staged. Since 1954 some thirty more trade stands have been packed into the hall; more and more business is transacted, and our stand continues to be a rendezvous where, on an average day, between ten and twenty farmers or merchants come to each District Advisory Officer with problems or requests. The exhibit also has an advisory value of its own. During the past year or two we have been trying to obtain some measure of this value and the following notes describe the simple form of evaluation attempted.

We have always tried to provide appropriate leaflets on the stand. These leaflets clearly played an important part because the exhibits are seldom completely self-explanatory and we are often dealing with enquiries on other matters. Leaflets on certain subjects proved more popular than others. If we counted the numbers taken each week we felt that we could measure not only the overall interest taken in our exhibits but also the relative importance attached by farmers and merchants to the information provided on different topics.

Analysing Leaflet Consumption at Exhibits

During the year 1956-57 forty-nine weekly exhibits were staged. On thirty of these occasions we provided free copies of suitable leaflets of which a total of 838 were taken away. They were taken only by the farmers, merchants and others closely concerned with the agricultural industry who pay to use the exchange. We make no attempt to distribute leaflets, nor have we noticed any farmer or merchant taking away more than one copy. On ten markets we provided no literature and on the remaining nine, for lack of suitable free leaflets, we sold appropriate bulletins and booklets to the value of £9 1*s*. 9*d*. We dislike selling literature and intend to restrict it to two markets per year when we hope to accommodate the Ministry's bookstall with a clerk attending.

A breakdown of the total of 838 free leaflets taken away reveals marked differences in the popularity of different subjects. All forty-eight available

copies of Advisory Leaflet No. 452 on Wild Oats were taken on one Friday in November 1956, twenty-nine of a stencilled handout on Spring Beans (based largely on an article by M. R. H. Soper in the "Agricultural Review") in January 1957, and thirty-five of Advisory Leaflet No. 104 on Pig Feeding in March 1957. The N.I.A.B. Farmers' Leaflets are always popular when we stage exhibits on recommended crop varieties. On the other hand, only ten copies of Growmore Leaflets No. 41 "When Land Needs Lime" were taken in June 1956, when we showed plants suffering from acidity and publicized the Summer Liming Subsidy. Similarly, although take-all and eyespot was one of the most popular subjects when we started these exhibits, interest has slackened in more recent years, undoubtedly partly because the extension of knowledge about its causes has led to a reduced incidence of this type of disease.

It may well be asked at this stage whether assessing the popularity of a subject by the number of leaflets taken up is a worthwhile guide to the present local importance of that subject. We think it a surprisingly accurate guide within limits. For instance, many local farmers are seriously in need of suitable cash crops to grow between cereals—hence the interest in spring beans. But crop failures through lack of lime are not now common in this area and the small take-up of leaflets on lime may reflect most farmers' confidence that they now understand this problem and have it under control.

Qualifying Factors

As in all attempts at evaluation of advisory methods, a number of qualifying factors and parallel influences need to be taken into account in considering the figures obtained. In the first place, *attendance at the Exchange varies*. In the busiest months after the beginning of harvest all the trade stands will be well staffed and up to 350 farmers will come in, but attendance gradually slackens throughout winter and spring until the weeks between May and the beginning of harvest when only about 100 farmers come in. Interest in our stand tends to vary according to the size of the market, but not in direct proportion because circulation is slower in the busy season and our small stand becomes crowded out. *Topicality* is another factor. It is particularly important, for instance, to pick the right week for exhibits on pests and diseases; interest in many farm products seems to flag when the market for them is depressed. Again, *the appearance of the leaflet* may affect the take-up, but we have little evidence of this beyond noticing that some short leaflets are sometimes read on the spot and replaced. Some of the most popular handouts have been locally duplicated.

It might also be thought that *the nature of the exhibit itself* would influence the amount of interest taken in the subject, that an eye-catching layout which tells a story would stimulate interest and lead to many leaflets being taken. We think that an attractive layout each week is important in the long term and helps to give our exhibit a certain prestige in the market, but it seems to be of secondary importance in determining

the demand for further information on any given subject. For instance, on the "Spring Beans" exhibit from which twenty-nine duplicated handouts were taken we showed only some well-corned stalks and samples of beans. In marked contrast was an exhibit on "Warble Fly", with electric light shining through a warbled hide, enlarged photographs showing treatment of affected animals, and samples of materials required. Farmers admired the exhibit but took few leaflets. They did not feel acutely the need for control, nor were they convinced of the practicability and profitability of control measures.

In fact, many exhibits will succeed in arousing interest only insofar as they fit into the pattern for effective advisory work. If enough farmers feel a problem acutely, if the Advisory Service has a profitable answer to that problem which has been tested and demonstrated locally, and if this answer is given supporting publicity, one has the makings of a successful exhibit. Our exhibits on barley manuring, for instance, have always attracted great interest, as is shown by the take-up of fifty duplicated handouts on this subject from our stand in September 1957. This is because barley is an important crop in this area, our advice is backed by a series of local field-trial demonstrations, and the exhibit is only part of a campaign which embraces newspaper publicity, farm meetings and individual advice.

Making Use of the Evaluation

Having collected these figures and considered their relevance and limitations, what use can we make of them? In advisory work the main purposes of evaluation have been described as threefold. It provides a basis of information upon which the work may be improved; gives if possible, a measure of success as a stimulus to the adviser, and supplies evidence to those responsible that the adviser's work is worthy of support. A first and obvious improvement to attempt in our Corn Exchange work is to ensure that enough suitable free leaflets are available at every exhibit. We have always been well served by the Ministry's Leaflet Room and the range of subjects covered by official Advisory Leaflets has increased very noticeably since 1950. There still remain some gaps, however, which we fill as best we can. Sometimes we can use the handouts printed for the Ministry's exhibits at Shows—for instance, the "Do your own Drainage" leaflets from the East Midland Provincial Show Exhibit of 1955 and the 1957 Royal Show handout on "Sprouting Seed Potatoes in Artificial Light". There remain a few subjects on which no ready-made handout is available or on which the available leaflet is unsuited to local conditions or out-of-date. We are now trying to fill these gaps by stencilling our own, often with the help of County and Specialist colleagues, who have always fully supported us in this Corn Exchange work. We have come to the conclusion that a subject on which there is no available leaflet, or for which it is not possible to produce a reliable one of practical value, is not in any case suitable for an advisory exhibit.

This counting of leaflets taken has also given us some guidance on where our efforts may best be directed. We hope to improve on our figures for 1956-57, but we fully realize that it is impossible to show a winner with a different subject every week. We like to cater for minority interests from time to time; we will continue to try to drive home the old lessons like the lime story, and we must try out new subjects such as indoor potato chitting by artificial light. Finally, this small trial evaluation has provided some encouragement to us as advisers. We know a little more about what we are doing and where we are going.

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